Enhanced Source Removal Using In-Situ Chemical Flushing

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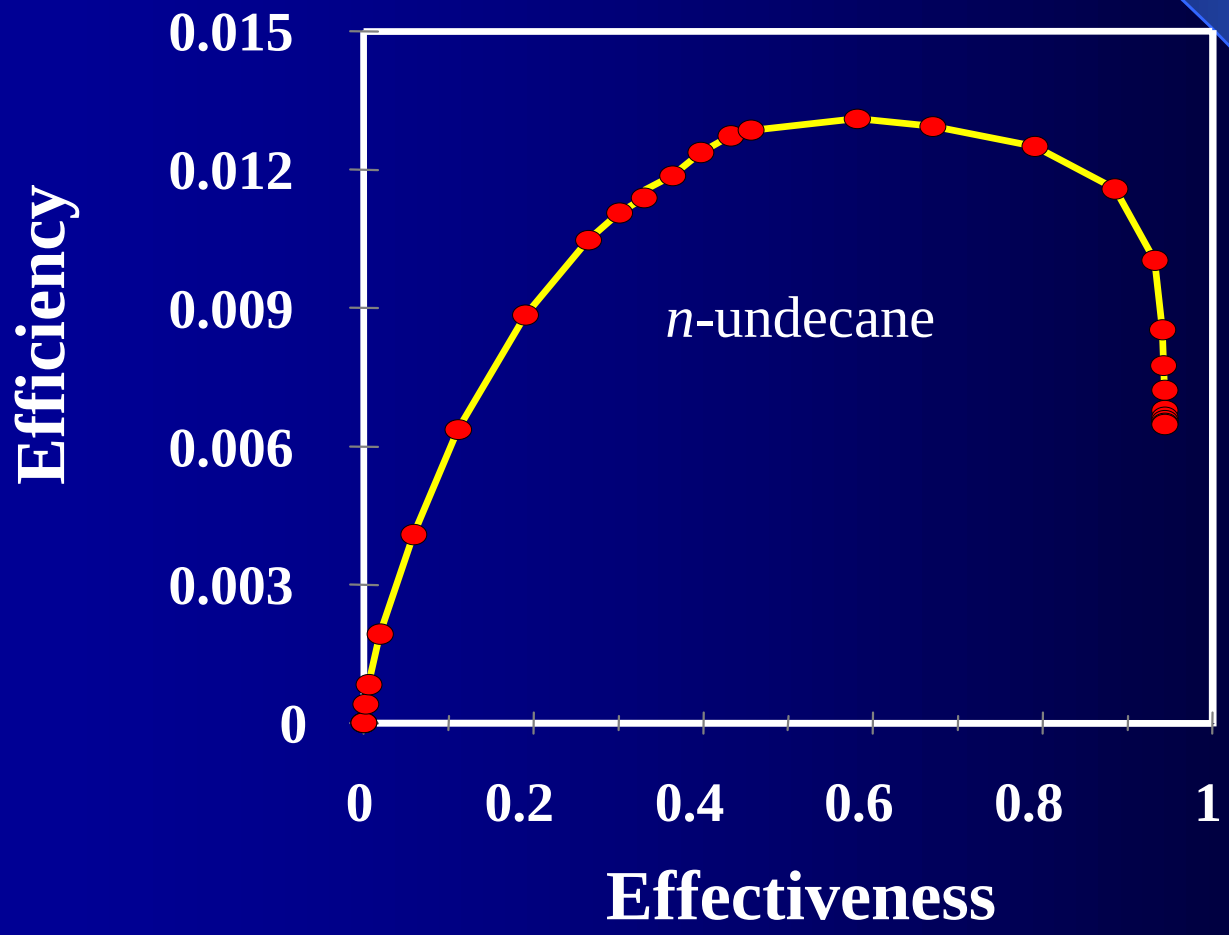
Outline

- ✓ Description of in-situ chemical flushing
- ✓ Effectiveness for DNAPL removal
- ✓ Benefits of DNAPL mass reduction
- ✓ Integrated source remediation with ISCF

In-Situ Chemical Flushing

- **Definition**
  - Displacement of fluid containing chemical adjuvants through contaminated soils or aquifers in order to enhance contaminant removal by enhanced dissolution or mobilization
- **Example Adjuvants**
  - Surfactants
  - Co-solvents
  - Complex Sugar

NAPL Removal Effectiveness



Efficiency Constraints

- ✓ Hydrodynamic variability
- ✓ DNAPL architecture
- ✓ Remedial fluid properties
  - density
  - viscosity
- ✓ Inadequate characterization

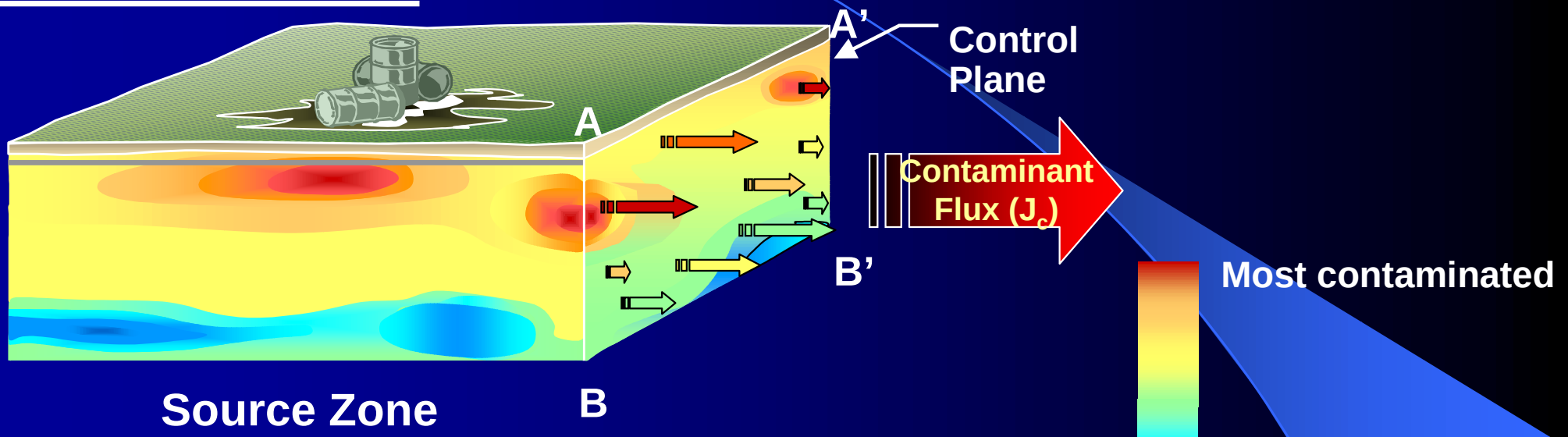
Mixing

Field Results

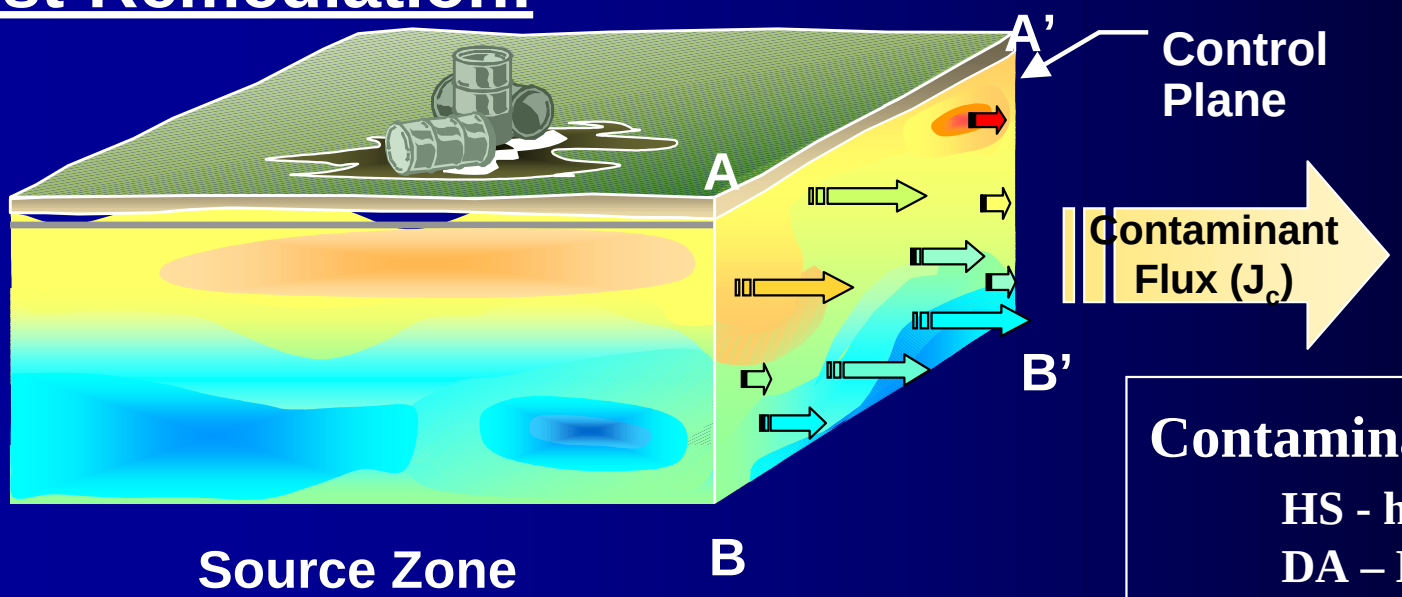
Site	DNAPL	Agent	Est. Mass Reduction
Hill AFB OU2	TCE	Surfactant	0.98
"	TCE	Surfact / foam	0.90
Camp Lejuene	PCE	Surfactant	0.72
Sages	PCE	Cosolvent	0.63
Dover	PCE	Cosolvent	0.64
"	"	Surfactant	0.67
"	"	Cosolvent	?
"	"	Cyclodextrin	?

Mass Reduction vs Mass Flux

Pre-Remediation:



Post-Remediation:

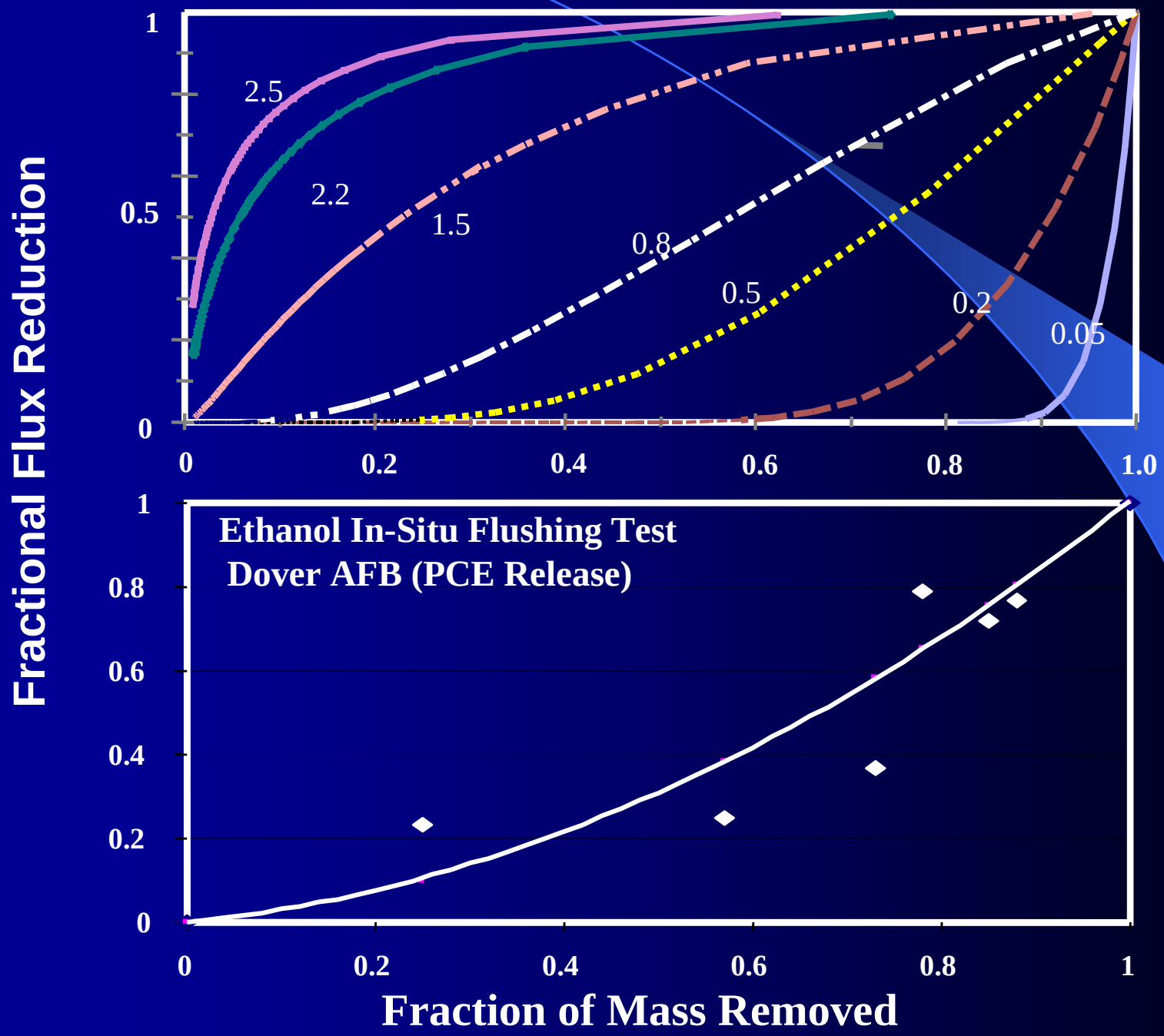


Contaminant flux = f (HS, DA)

HS - hydrodynamic structure

DA – DNAPL architecture

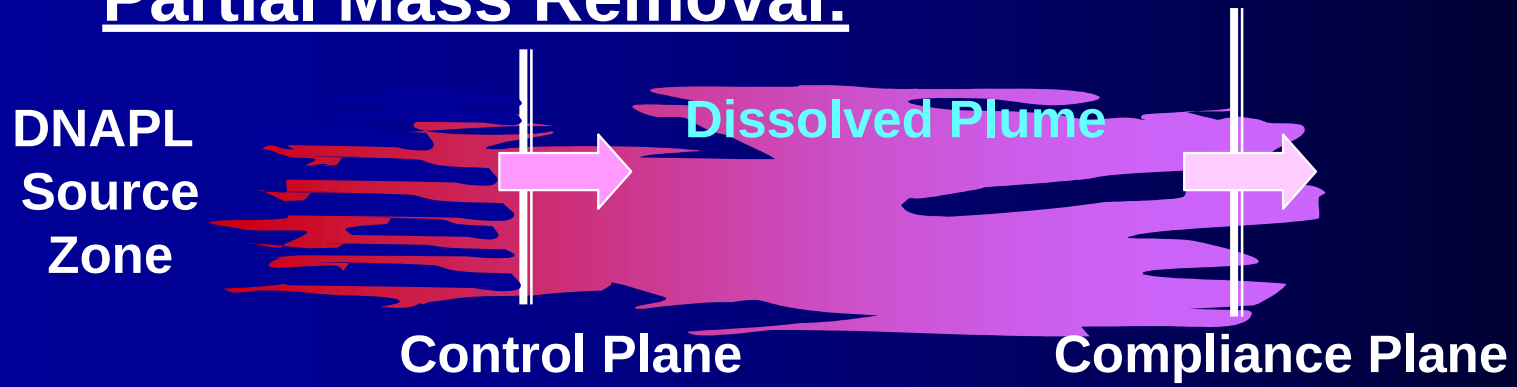
Mass Reduction vs Mass Flux



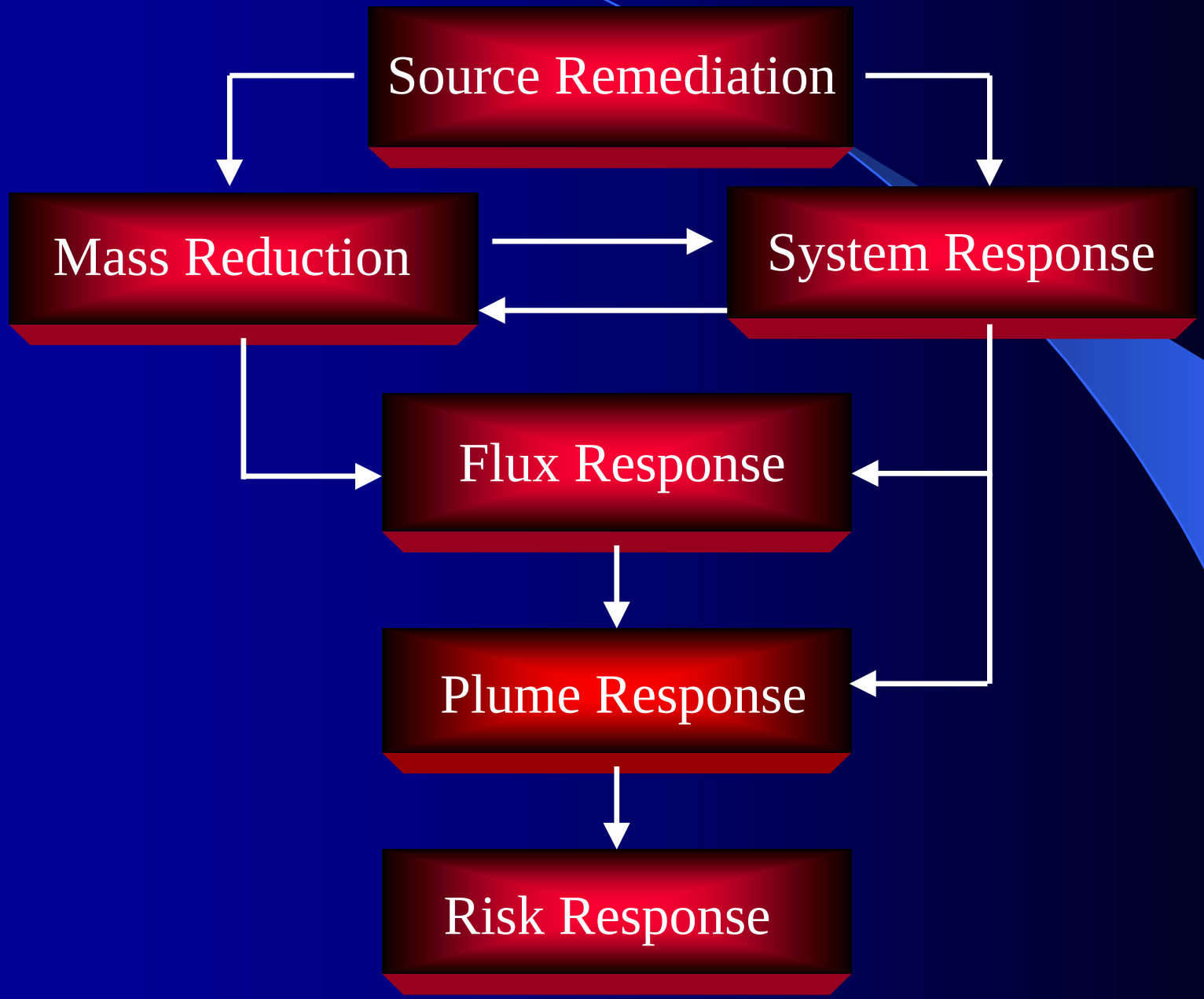
PLUME RESPONSE

Pre-Remediation:

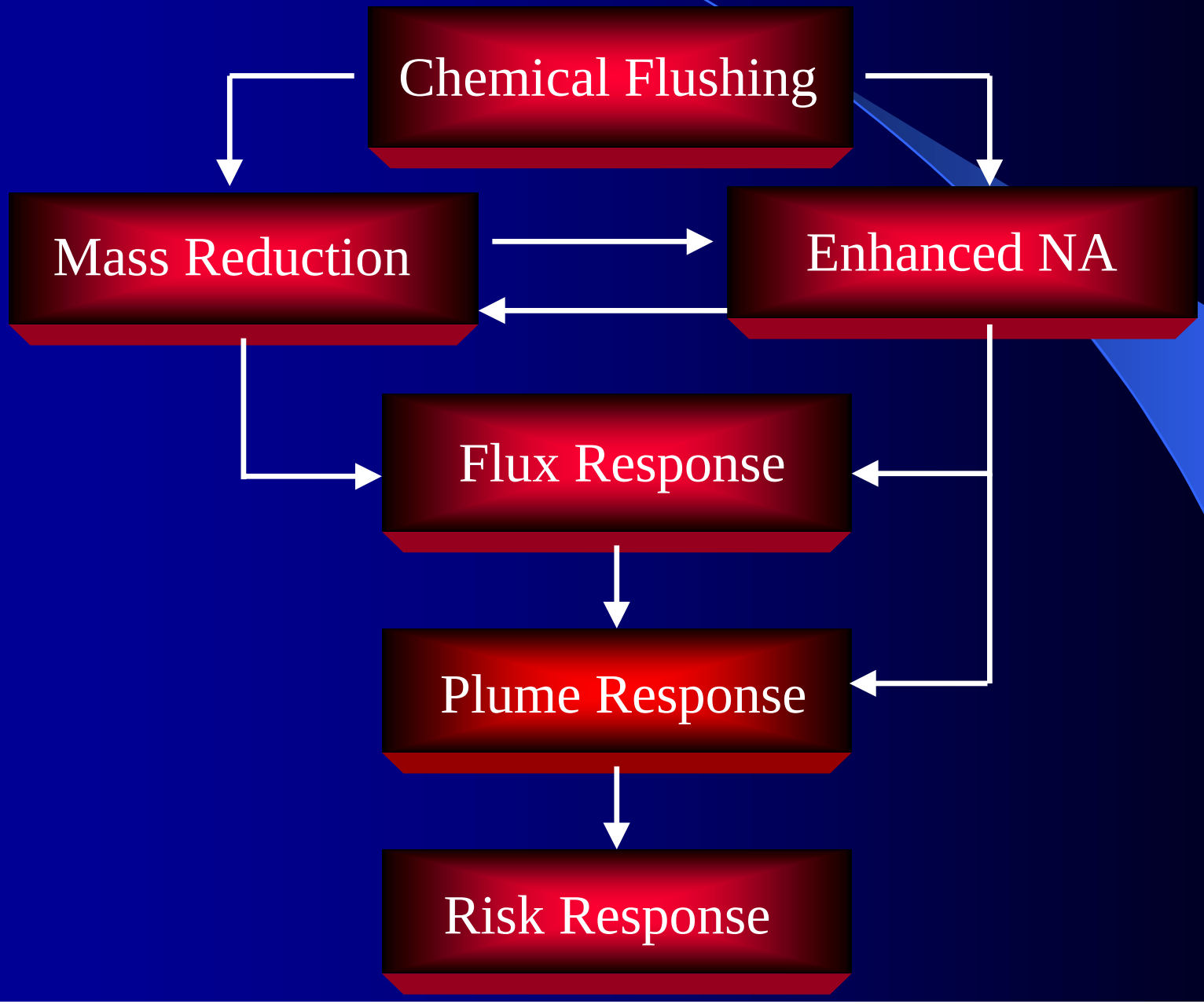
Partial Mass Removal:



Conceptual Model



Integrated Source Remediation:
Chemically Augmented NA (CANA)

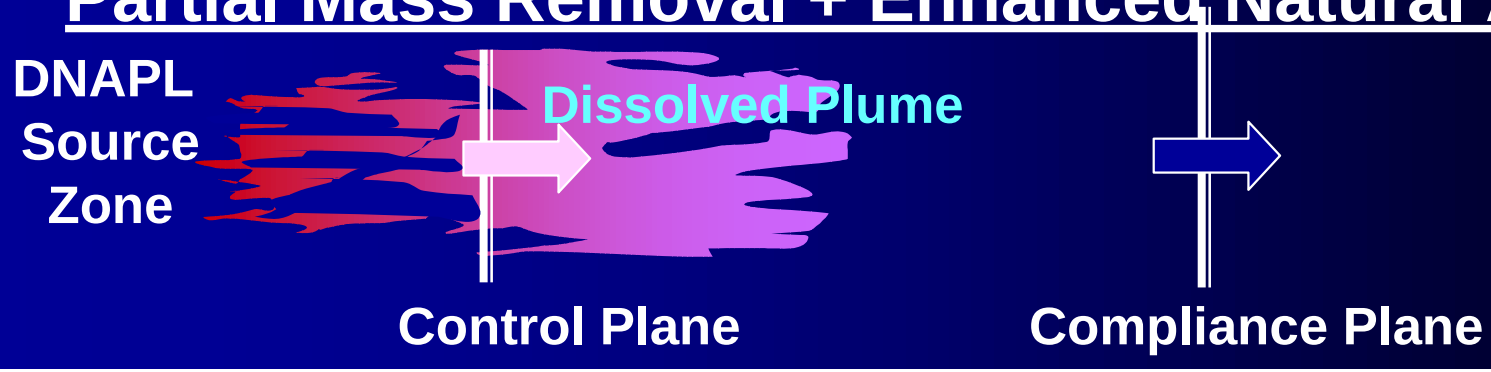


PLUME RESPONSE

Pre-Remediation:

Partial Mass Removal:

Partial Mass Removal + Enhanced Natural Attenuation:



Integrated Source Remediation:

- Target DNAPL Source Zone
- Integrate Remediation Technologies into a Treatment Train for Comprehensive Site Restoration
- Decrease Remediation Costs

Integrated Source Remediation:
Solvent Extraction Residual Biotreatment (SERB)

Field Demonstration: Sages Site

- **CoSolvent Extraction (SE)**
  Selective removal of DNAPL (PCE) by cosolvent flushing with ethanol

- **Residual Biotreatment (RB)**
  Passive removal of dissolved phase PCE by enhanced reductive dechlorination (biodegradation)

Cosolvent Flush Performance*

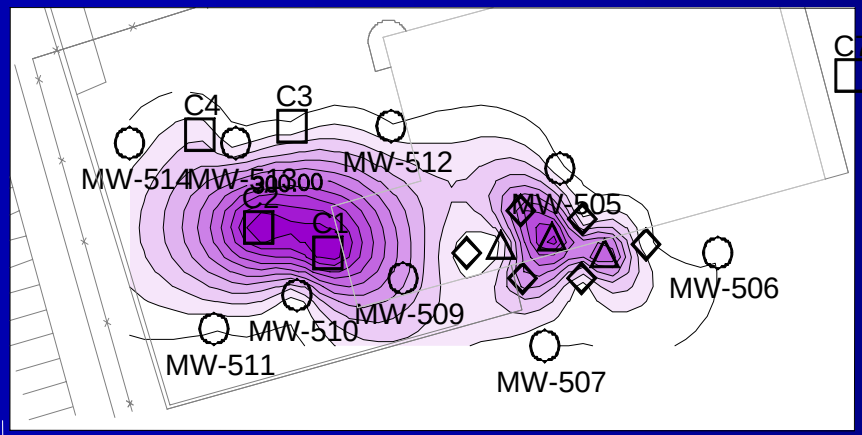
Pre-Cosolvent Flush Partitioning Tracer	68 L (PCE)
Post-Cosolvent Flush Partitioning Tracer	26 L (PCE)
Estimated Recovery Based on Partitioning Tracer Tests	42 L (PCE) (62%)
Mass Recovery Based on PCE Concentrations in Recovery Wells	43 L (PCE) (63%)
Mass Recovery Based on Post/Pre Cores	(65%)

*** Jawitz et al., 2000**

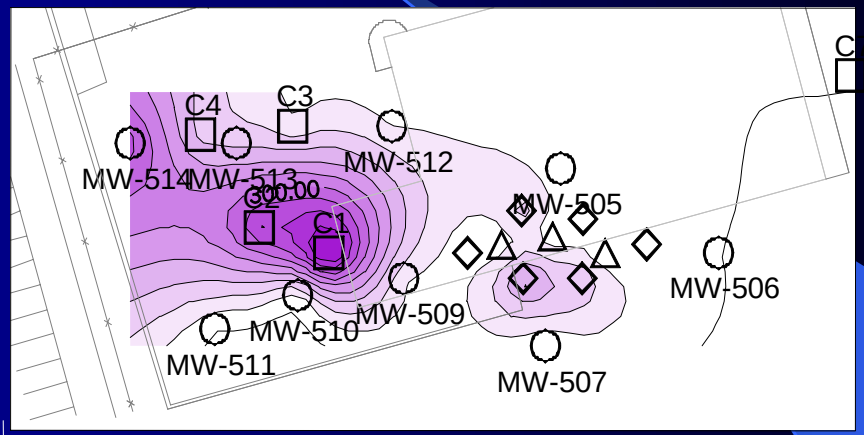
Residual Biotreatment Performance

PCE (500 uM = 83 mg/L)

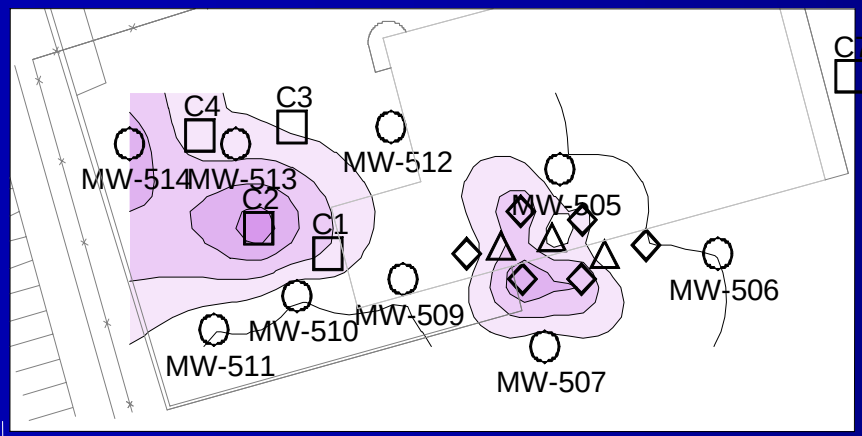
Pre-Ethanol Flush



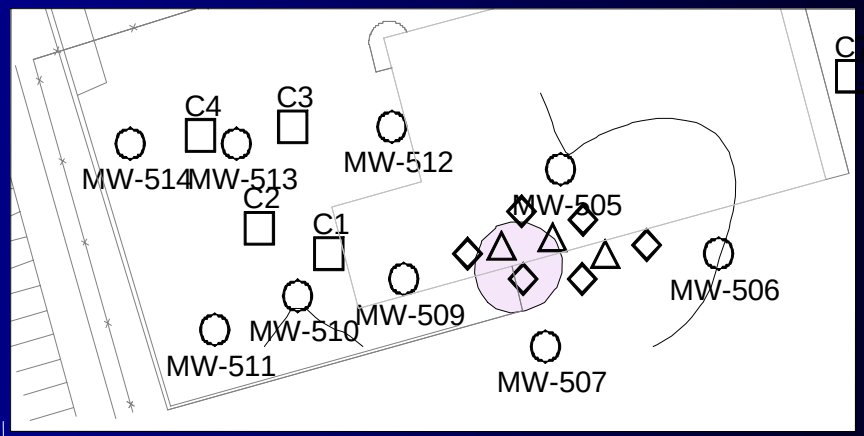
~1 Month Post-Flush

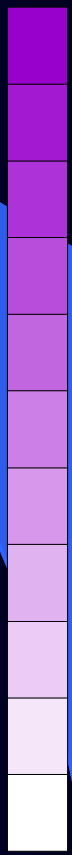


~13.5 Months Post-Flush



~25 Months Post-Flush



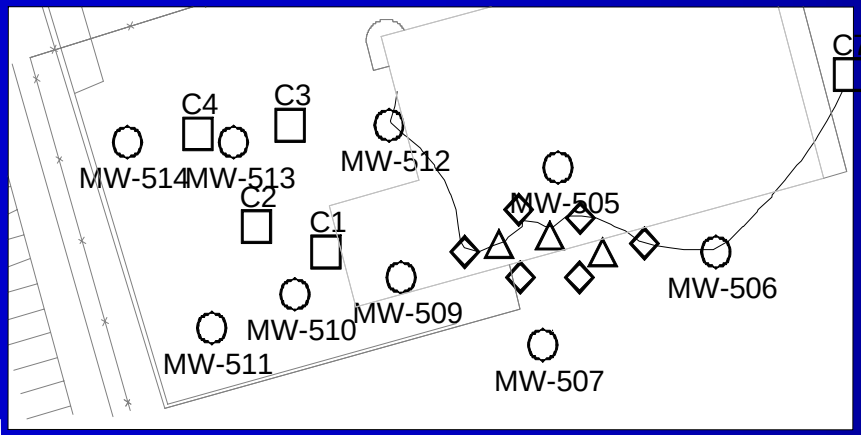


500 uM
450 uM
400 uM
350 uM
300 uM
250 uM
200 uM
150 uM
100 uM
50 uM
0 uM

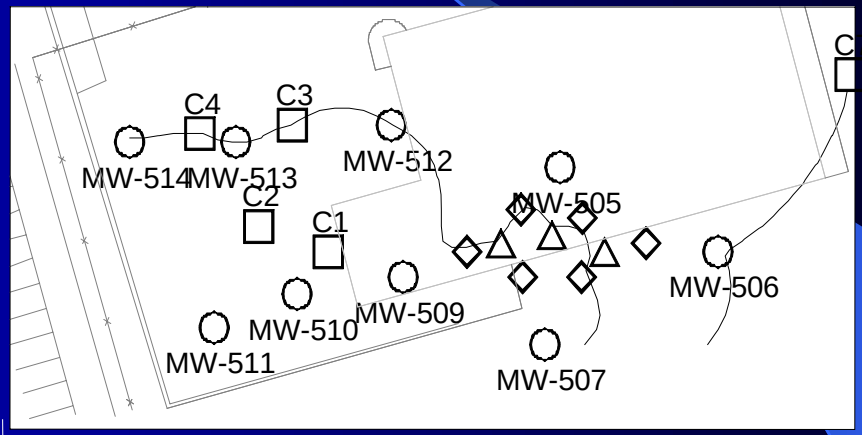
Residual Biotreatment Performance

cis-DCE (175 uM = 17 mg/L)

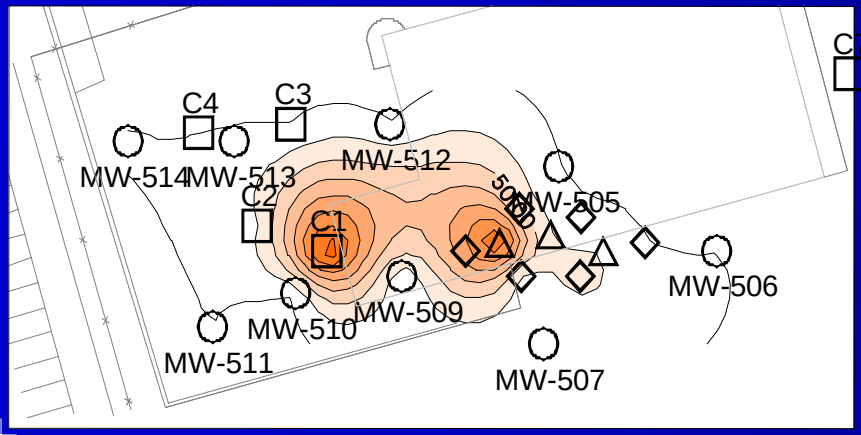
Pre-Ethanol Flush



~1 Month Post-Flush



~13.5 Months Post-Flush



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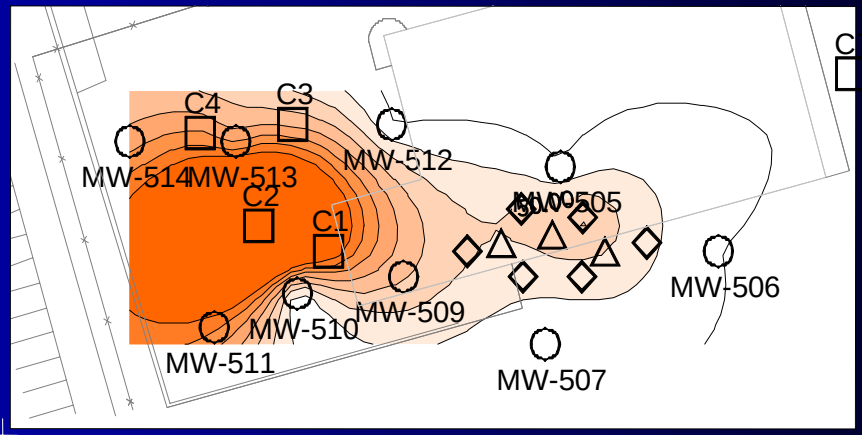
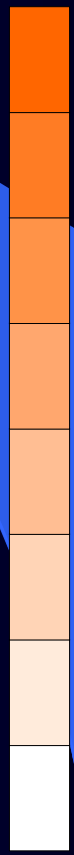


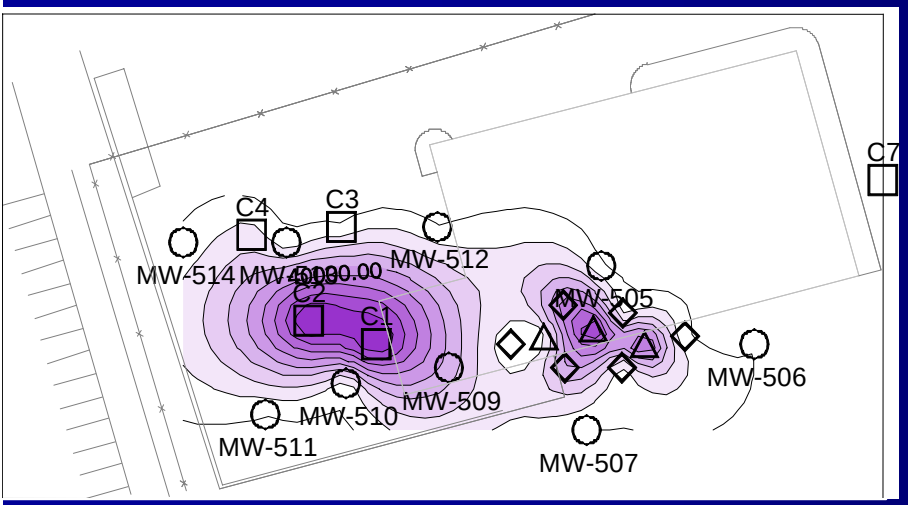


175 uM
150 uM
125 uM
100 uM
75 uM
50 uM
25 uM
0 uM

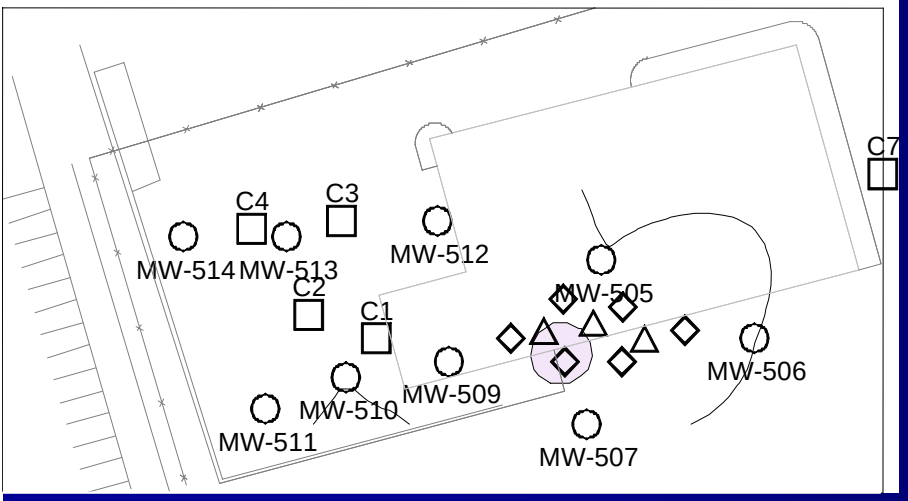
OBSERVED PLUME RESPONSE

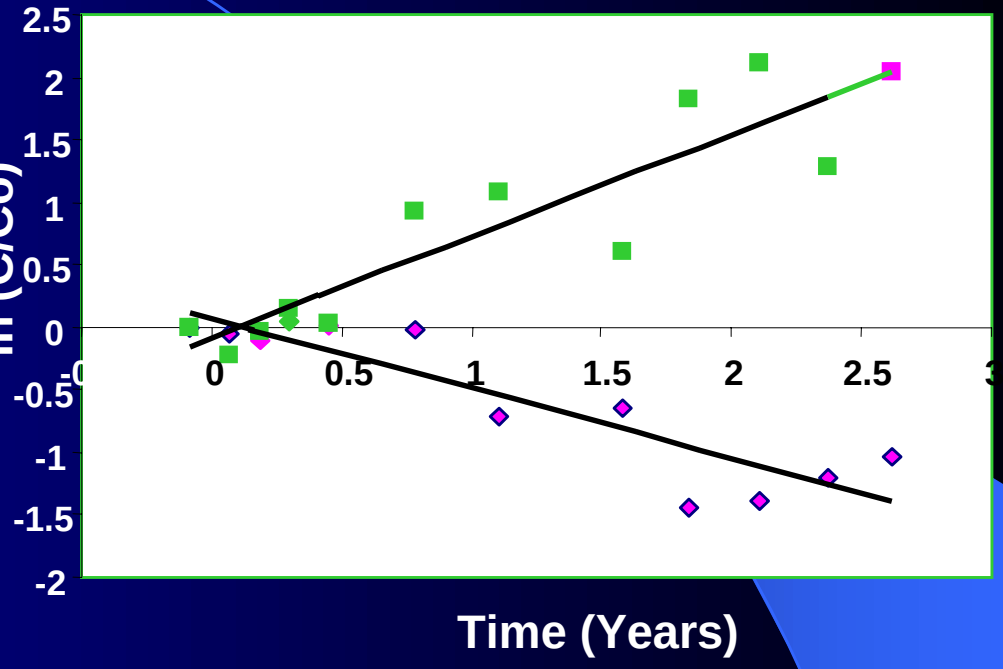
SAGE'S DRY CLEANER SITE

Pre-Ethanol Flush



~25 Months Post-Flush





	k (1/yr)	$t_{1/2}$ (yr)
cis-DCE	0.81	0.9
PCE	-0.56	1.2

Summary

- Substantial DNAPL mass reduction can be achieved using ISCF
- Complete mass removal is generally not economically or technically feasible
- Correlation between mass reduction and mass flux is poorly understood
- Integrated DNAPL remediation approaches that incorporate technology coupling (treatment trains) are needed to improve efficiency and reduce costs